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PROCEDURES FOR ESTIMATING ALBACORE LENGTH-FREQUENCY DISTRIBUTIONS FOR THE NORTH PACIFIC

By

Christina H. Perrin and Earl C. Weber

ADMINISTRATIVE REPORT LJ-88-02

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1. INTRODUCTION

Albacore (Thunnus alalunga) in the North Pacific is an important resource to U. S. fishermen and consumers alike. The North Pacific harvest of this species is shared by several nations, but the Japanese with their surface and longline fisheries take by far the greatest amount. Considerable amounts of the foreign-caught North Pacific albacore are believed to enter the United States' import market to meet a heavy consumer demand for "white meat" tuna (Bartoo et al. 1979).

The international management of North Pacific albacore is informal, consisting chiefly of a workshop series initiated by the Southwest Fisheries Center (Holts and Bartoo 1985). These workshops permit the timely exchange of research results and fishery data. The Southwest Fisheries Center has also developed a strategic planning process designed to identify research needs and has developed an operational plan for implementing such research (Parrish et al. 1985). The operational plan calls for, in part, an age-structured investigation into the relationships between fishery and environmental indices. An early step in such an investigation is a study to determine the age structure of albacore catches in the North Pacific for all major fisheries. This age structure analysis depends on knowing the catch at age, which must be estimated from length. Existing data consist of length-frequency, catch-and-effort and total catch data. In order to develop the catch-at-age estimates, the catch statistics obtained from existing length-frequency data must be raised and transformed so that the final raised length-frequency data correspond with the total catch reported. The purpose of this document is to describe the data sources used and the procedures followed to develop the raised length-frequency data base on which the aging study is based.

2. DATA SOURCES

The raised length-frequency data base for North Pacific albacore contains data for the Japanese baitboat, Japanese longline, and the U.S. jig fishery[1]. The Japanese baitboat and longline fisheries are covered for the years 1960 to 1982 and the U.S. jig fishery for the years 1961 to 1982. Three types of information are available for each fishery: total catch, length-frequency data, and catch-and-effort data.

2.1. Total catch report

The data on total catch for North Pacific albacore come from various countries and are summarized by Majors and Miller (1986). Table 3, "Catches for North Pacific albacore in metric tons, 1952-1985" from Majors and Miller (1986) is attached as Appendix 1.

2.2. Length-frequency data

The original three sets (fisheries) of length-frequency data are records of randomly sampled fish sizes made on board fishing vessels at sea or at landing ports in Japan and the United States. Each data set consists of 23 (22 for the U.S. jig fishery) files, and each file contains one year of data. Each file contains hundreds to thousands of records, and each record represents the length-frequency distribution (lengths recorded in 1-centimeter intervals) for a group of sampled fish caught in the same month and area.

The area units used in these data sets are not standardized within and between the fisheries. The following table displays the time-area units used and the data sources for each of the North Pacific albacore fisheries. The information is extracted from the Report of the Fifth North Pacific Albacore Workshop (Bartoo 1981).

North Pacific albacore length-frequency data and sources

Fishery	Year	Time-area Unit	Source
Japanese longline	60-64	year, month, 10° long. bands 1-cm increments	Koto & Hisada (1966)

[1] Includes small amounts of baitboat and purse-seine catches.

Fishery	Year	Time-area Unit	Source
Japanese longline	65-82	year, month, 5° x 10° squares 1-cm increments	65-71 in Shiohama(1973) 72-82 from FSFRL[1]
Japanese baitboat	60-64	year, month, 10° long. bands 1-cm increments	Koto & Hisada (1966)
Japanese baitboat	65-82	year, month, 5° x 10° squares 1-cm increments	65-71 in Shiohama(1973) 72-82 from FSFRL[1]
U.S. jig	61-82	year, month, 1° x 1° squares 5° x 5° squares 1-cm increments	NMFS[2]

2.3. Catch-and-effort data

The catch-and-effort data are also in separate files. Each file contains data for one year. The units of time and area used in these data are not consistent for all three fisheries (Kleiber and Baker 1986). The following table lists the various units used in different years.

North Pacific albacore catch-and-effort data

Fishery	Year	Catch unit	Time-area Unit	Effort Unit
Japanese longline	60-82	# of fish	year, month, 5° x 10° squares	# hooks, # sets
Japanese baitboat	55-69	# of fish	year, month, 5° x 10° squares	# fishing trips

[1] Far Seas Research Laboratory, Shimizu, Japan.

[2] National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, California, U.S.A.

Fishery	Year	Catch Unit	Time-area Unit	Effort Unit
Japanese baitboat	70-79	M. tons	year, month, 5° x 10° squares	# fishing days
Japanese baitboat	80	M. tons	year, month, 1° x 1° squares	# poles used
Japanese baitboat	81-	M. tons	year, month, 5° x 5° squares	# poles used
U.S. jig	61-82	# of fish	year, month, 1° x 1° squares, 5° x 5° squares	# fishing days

3. RAISING PROCEDURES

Different raising procedures were used in processing the several data files because the time-area units for the source data are not uniform. The end result is a separate file for each fishery and each year. For data grouping purposes, we used a set of 10 geographical model areas (Appendix 2) that had previously been used at SWFC to define albacore target areas (Kleiber and Baker 1986). The data in each final raised length-frequency file were grouped by the model areas and months for which data exist. The following example of the raising steps refers to the Japanese longline fishery; slight differences relating to the Japanese baitboat and U.S. jig boat fisheries are described in Section 4 on "Variations in procedures." The data were raised one year at a time. Different area grouping units were chosen in the first step.

3.1. First step

Since the available length-frequency data for 1960-1964 are in 10° longitudinal bands, the appropriate data grouping strata for this period were by year, by month, by model area and by 10° longitudinal band. From 1965 to 1982, the data were grouped by year, by month and by 5° x 10° square. An extra step was taken in preparing the length-frequency data for 1960-1964; when data overlapped two or more model areas, the same length-frequency was duplicated for each overlapped area.

The data in the length-frequency file were checked at first and if suitable were combined into the above specified time-area strata before the raising. The same procedure was applied to the catch-and-effort data. Records with the following type of information were unsuitable for grouping

and were discarded: a) unspecified latitude and longitude readings or readings that fell outside of the 10 geographical model area boundaries, b) month codes not between 1-12, and c) area unit larger than the chosen area stratum.

After the data were combined, we used the length-frequency data file and the catch-and-effort data file for the same year to compare the total catch for each time-area stratum individually. When data existed in both files for any time-area stratum, the individual 1-cm length-frequencies were multiplied by a factor, so that the total number of fish was equal to the total catch reported from the same time-area stratum in the catch-and-effort data. The multiplying factor was calculated using the following equation:

$$R(i,j,k) = C(i,j,k) / L(i,j,k) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where

i = ith year
j = jth month
k = kth area stratum
R(i,j,k) = raising factor for cell i,j,k
C(i,j,k) = catch total from the catch-and-effort data
L(i,j,k) = summation of the total number of fish in the length-frequency

From equation 1 we derive:

$$C(i,j,k) = R(i,j,k) * L(i,j,k)$$

$$= R(i,j,k) * \sum_{l} L(i,j,k,l)$$

$$= \sum_{l} (R(i,j,k) * L(i,j,k,l)) \quad \ldots\ldots\ldots\ldots (2)$$

where

l = the lth length-class.

Therefore, in the procedure each lth length-frequency in the ith year, jth month and kth area cell was multiplied by the factor R(i,j,k).

Note that the area strata for 1960-1964 are by 10° longitudinal band and by model area, whereas the data for 1965-1982 were grouped into 5° x 10° squares. For areas with catches but no length-frequencies, these catch figures were ignored but redistributed later in the second step.

3.2. Second step

The rationale here is similar to that in the first step, except that the time-area strata used were month and model area. The partially raised length-frequency data were grouped together by year, by month, by model area and by 1-cm increments. The catch-and-effort data were combined by the same time-area strata.

For the areas with both length frequencies and sample catches, we multiplied the length-frequencies by a factor to make the summation of the number of fish in the length frequency for each stratum equal to the total sample catch from the same time-area stratum. The multiplying factor was calculated using Equation 1. Note that the index k represents the model area.

For areas where there was sample catch but no length-frequency distribution, we substituted a length-frequency distribution from an area as close as possible temporally as well as geographically. For most situations, a length-frequency distribution was chosen that had the same month coding as the sample catch and had the appropriate model area code:

Model area code of the sample catch	Model area code of the substituted length-frequency

(Use the first code that appears on this list. If there are no data for this area, then use the next in the sequence, etc.)

1	1 -> 2 -> 10 -> 9.
2	2 -> 1 -> 9 -> 10.
3	3 -> 4 -> 2 -> 7.
4	4 -> 3 -> 5 -> 7.
5	5 -> 7 -> 4 -> 3.
7	7 -> 2 -> 3 -> 5.
8	8 -> 9 -> 7.
9	9 -> 8 -> 2.
10	10 -> 9 -> 1.

These hierarchies represent adjacent model areas in which the same sized albacore could reasonably be expected to be caught within any given month.

When this failed to provide an appropriate substitute model area, then each unmatched catch stratum had to be dealt with individually. From a list of all available length-frequencies, we selected a length-frequency that was from an area as close as possible to the area and month of

the unmatched catch. All substitutions were made within the same fishery and the same year.

After the substitution was made, the total frequency was multiplied by a factor (using Equation 1) so that the summation of the number of fish in the length-frequency was equal to the total catch found in the corresponding monthly model-area stratum of the catch-and-effort data.

The result of the second step was a set of length-frequency data files from 1960-1982 that were further raised. Each file contained raised length-frequencies for each month-model-area fished for a year.

3.3. Final step

The last step was to increase or decrease proportionally the individual length frequencies so the total frequency (total number of fish) for the year was equal to the total catches reported. Since the total catches are reported in metric tons (Majors and Miller 1986), transformation from the length representation to a weight representation was necessary; this was done using a length-weight equation (Clemens 1961), where weight is in pounds and length is in millimeters:

$$\text{Weight} = 0.4936 * 10^{-7} * \text{length}^{2.99} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

The total weight for each stratum was calculated using this equation:

$$Wt(i,j,k) = \sum_{l} (F(i,j,k,l) * 0.4936 * 10^{-7} * (l * 10)^{2.99})$$

The total catch for the ith year was calculated by summing all monthly-model-area frequencies together:

$$Twt(i) = \sum_{j} \sum_{k} \sum_{l} Wt(i,j,k,l)$$

Then the weight was converted to tonnage :

$$Ton(i) = \left(\sum_{j} \sum_{k} \sum_{l} (F(i,j,k,l) * 0.4936 * 10^{-7} * (10*l)^{2.99}) \right) / 2204.6$$

where

i = year
j = month
k = model area
l = length in cm
F(i,j,k,l)= number of fish in cell (i,j,k,l)
Ton(i)= total weight(tonnage) for ith year.

The multiplying factor R(i) was calculated by:

R(i) = Catch(i) / Ton(i)

where

i = year
Catch(i) = Total catch reported for ith year
Ton(i) = Total tonnage calculated from the length-frequency data for ith year.

4. VARIATION IN PROCEDURES

No standard raising procedures could be applied to each of the input data files, because the data sources vary from gear to gear and area resolution varies from year to year. The final raised length-frequency data, however, are quite uniform in resolution.

The raised Japanese longline and baitboat length-frequency files are in one format (see Appendix 3), whereas the data for the U.S. jig boats are in a slightly different format (see Appendix 4) since they were processed a year earlier. For the Japanese baitboat data from 1970-1982, transformation from length to weight is performed at the first step because the catch is in metric tons.

The data for the U.S. jig fishery are grouped by month and by model area at the first step, and the 10 geographical boundaries are at 20° N instead of at 25° N; the 25° N boundary is used for the other two fisheries for model areas 1, 2, 7, 5, 10, 9, 8, 6. Data for the baitboat fishery and the longline fishery are divided at 25° N because the catchabilities are expected to be different on the two sides of this line for the Japanese fisheries (Kleiber and Baker 1986).

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Table 3. Catches for North Pacific albacore in metric tons, 1952-1985.

Year	Japan					Taiwan	United States				Canada	Grand Total
	Bait boat	Long-line	Gill net	Other gear	Total	Long-line	Bait boat	Jig-boat	Sport	Total	Jig-boat	
1952	41,386	26,687	-	237	68,310	-	-	23,843	1,373	25,216	71	93,597
1953	32,921	27,777	-	132	60,830	-	-	15,740	171	15,911	5	76,746
1954	28,069	20,958	-	38	49,065	-	-	12,246	147	12,393	-	61,458
1955	24,236	16,277	-	136	40,649	-	-	13,264	577	13,841	-	54,490
1956	42,810	14,341	-	57	57,208	-	-	18,751	482	19,233	17	76,458
1957	49,500	21,053	-	151	70,704	-	-	21,165	304	21469	8	92,181
1958	22,175	18,452	-	124	40,751	-	-	14,855	48	14,903	74	55,728
1959	14,252	15,502	-	67	29,821	-	-	20,990	0	20,990	212	51,023
1960	23,156	17,369	-	76	40,601	-	-	20,100	557	20,657	5	61,263
1961	18,636	15,764	-	268	34,668	-	2,837	12,061	1,355	16,253	4	50,925
1962	8,729	13,464	-	191	22,384	-	1,085	19,760	1,681	22,526	1	44,911
1963	26,420	15,458	-	218	42,096	-	2,432	25,147	1,161	28,740	5	70,841
1964	23,858	13,701	-	319	37,879	26	3,411	18,392	824	22,627	3	60,535
1965	41,491	25,050	-	121	56,662	16	417	16,545	731	17,693	15	74,386
1966	22,830	28,869	-	585	52,284	16	1,600	15,342	588	17,530	44	69,874
1967	30,481	23,961	-	520	54,962	17	4,113	17,826	707	22,646	161	77,786
1968	16,597	23,061	-	1,109	40,767	15	4,906	20,444	951	26,301	1,028	68,111
1969	32,107	18,006	-	1,480	51,593	21	2,996	18,839	358	22,193	1,365	75,172
1970	24,378	15,372	-	956	40,706	23	4,416	21,041	822	26,279	345	67,353
1971	53,198	11,035	-	1,262	65,495	24	2,071	20,537	1,175	23,783	1,587	90,889
1972	60,762	12,649	1	921	74,333	25	3,750	23,608	637	27,995	3,558	105,911
1973	69,811	16,059	39	1,883	87,792	35	2,236	15,667	84	17,987	1,270	107,084
1974	73,576	13,053	224	1,065	87,918	40	4,777	20,187	94	25,058	1,207	114,223
1975	51,157	10,060	166	402	61,785	28	3,243	18,975	640	22,858	101	84,772
1976	83,336	15,896	1,070	1,394	101,696	37	2,700	15,932	713	19,345	252	121,330
1977	31,934	15,737	688	1,039	49,398	61	1,497	10,005	537	12,039	53	61,551
1978	59,877	13,061	4,029	3,209	80,176	53	950	16,682	810	18,442	23	98,694
1979	44,662	14,249	2,856	1,280	63,047	81	303	6,801	74	7,178	289	70,595
1980	46,743	14,743	2,986	1,516	65,988	-	382	7,574	168	8,124	212	74,324
1981	27,426	18,020	17,425	956	63,827	-	748	12,694	195	13,637	98	77,562
1982	29,615	16,762	17,947	1,054	65,378	-	425	6,661	257	7,343	1	72,722
1983	21,098	15,103	9,160	471	45,832	-	607	9,512	87	10,206	64	56,102
1984	26,000	-	-	-	-	-	832	9,576	1,427	15,563[7]	18	-
1985	-	-	-	-	-	-	872	7,059	1,176	9,107	1	-

Remarks:

1. Figures for 1984-85 are preliminary.
2. Japanese longline catches for 1952-60 exclude minor amounts taken by vessels under 20 tons. Longline catches in weight are estimated by multiplying annual number of fish caught by average weight statistics.
3. Japanese baitboat catches include catches by research vessels.
4. U.S. Jigboat catches for years 1952-60 include baitboat catches.
5. United States sport catch is a minimum estimate based on partial coverage.
6. U.S. catches from 1961 to 1985 include Hawaii.
7. United States total for 1984 include catches (3,728 mt) by purse seines.

Appendix 2. Figure 4 from Kleiber & Baker (1986). Geographical zones used by simulation model.

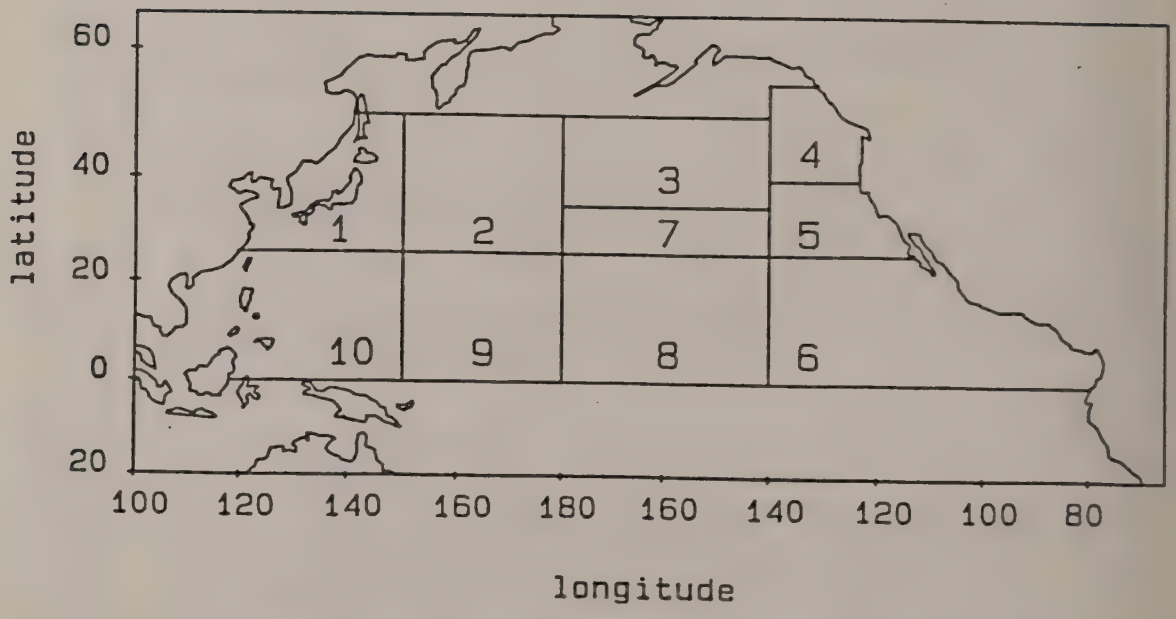

Figure 4. Geographical zones used by simulation model.

Appendix 3. Raised Japanese North Pacific albacore length-frequency data format(tape: "RLFRQ",1st-46th files)

1. Header record.

COLUMNS	FORMAT	VARIABLES	COMMENTS
1 - 2	i2	Year	60-82
3 - 4	i2	Model area	1-10
5 - 6	i2	Month	1-12
7 - 8	i2	Gear	1= longline 2= jig 3= baitboat
9 -11	i3	Beginning fish length	25 cm
12 -14	i3	Ending fish length	134 cm
15 -24	i10	Total frequency on record	(Raised)
25 -34	i10	Total unraised frequency	

Data records:

COLUMNS	FORMAT	VARIABLES	COMMENTS
1 - 8	i8	1st length-frequency	Number of albacore
9 -16	i8	2nd length-frequency	"
17 -24	i8	3rd length-frequency	"
25 -32	i8	4th length-frequency	"
33 -40	"	5th "	"
41 -48	"	6th "	"
49 -56	"	7th "	"
57 -64	"	8th "	"
65 -72	"	9th "	"
73 -80	"	10th "	"

Note: All data records contain 10 frequency entries. There are 11 data records following each header record.

Appendix 4. Raised U. S. North Pacific albacore length-frequency data format(tape: "RLFRQ", 47-68th files)

COLUMNS	FORMAT	VARIABLES	COMMENTS
1 - 2	i2	Year	61-84
3 - 4	i2	Model area	1-10
5 - 6	i2	Month	1-12
7 - 8	i2	Gear	2 (jig)
9 -11	i3	Beginning fish length	35 cm
12 -14	i3	Ending fish length	125 cm
15 -24	i10	Total frequency on record	(Raised)
25 -34	i10	Total effort	
35 -44	i10	Total unraised frequency	

2. Data records:

COLUMNS	FORMAT	VARIABLES	COMMENTS
1 - 8	i8	1st length-frequency	Number of albacore
9 -16	i8	2nd length-frequency	"
17 -24	i8	3rd length-frequency	"
25 -32	i8	4th length-frequency	"
33 -40	"	5th "	"
41 -48	"	6th "	"
49 -56	"	7th "	"
57 -64	"	8th "	"
65 -72	"	9th "	"
73 -80	"	10th "	"

Note: All data records contain 10 frequency entries except the last data record where only one frequency is found. There are 10 data records following each header record.